2007 DOE Hydrogen Program Review
Validation of an Integrated Hydrogen Energy Station

Dan Tyndall

Air Products and Chemicals, Inc.

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Project TV-06

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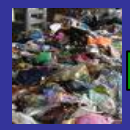
Hydrogen Energy Station Vision
- High-Efficiency and Renewable -



CO_2

H_2 Energy and Fueling Station

Biogas

Heat

Power

Heat

H_2

H_2/CNG

Neighborhoods

Farms

Businesses

Ethanol

Laundromat

Feedstock Generation

- Municipal Digester Gas
- Landfill Gas
- Ethanol / Agricultural Wastes
- Pyrolysis Gas
- Bio-Syngas / Syngas
- Vegetable Oils / Oils
- Other Methane Sources (e.g., coal-bed)

Biogas
Hydrogen
Power
Heat

AIR PRODUCTS

Hydrogen Energy Station
Distributed Power and Hydrogen

FuelCell Energy DFC-300

35%
Power

10%
Heat

End User

Air Products Purification

30%
H_2

Hydrogen Filling Station

FuelCell Energy

AIR PRODUCTS

Overview – Integrated Hydrogen Energy Station

Timeline

- Start – Sep. 30, 2001
- End – Mar. 31, 2009
- 20% Budget Complete
- 75% Schedule Complete

Budget

- Total Project Funding
  - DOE share: $5.2 MM
  - APCI + Partners: $5.2 MM
- FY06 Funding: $1.3 MM
- FY07 Funding: $2.1 MM
- Proposed Mod for Digester Gas Under Review

HFCIT Barriers

- C. H2 Fueling Infrastructure
- I. H2 & Power Co-Production

HFCIT Targets

- Cost of H2: $3.00 /kg
- Electrical Efficiency > 40%

Partners

- FuelCell Energy
  - MCFC, Fuel Prep, WGS
- NFCRC – Outreach / Validation
- OCSD – Host Site (CA)
- CA – ARB, AQMD, CEC, SCE
- Alternative Feedstocks - Various

Objectives by Phase

- Overall - Determine the economic and technical viability of a hydrogen energy station designed to co-produce power and hydrogen

- Phase 1 - Feasibility: Evaluated PEM and HTFC (Completed FY03-04)

✓ • Phase 2 - Preliminary System Design (Completed FY-06)

✓ • Phase 3: Detailed Design and Construction In Progress (FY07 – 08)

- Phase 4: Operation, Testing, Data Collection Future Work (FY08 – 09)

Phase 2 - Preliminary Design

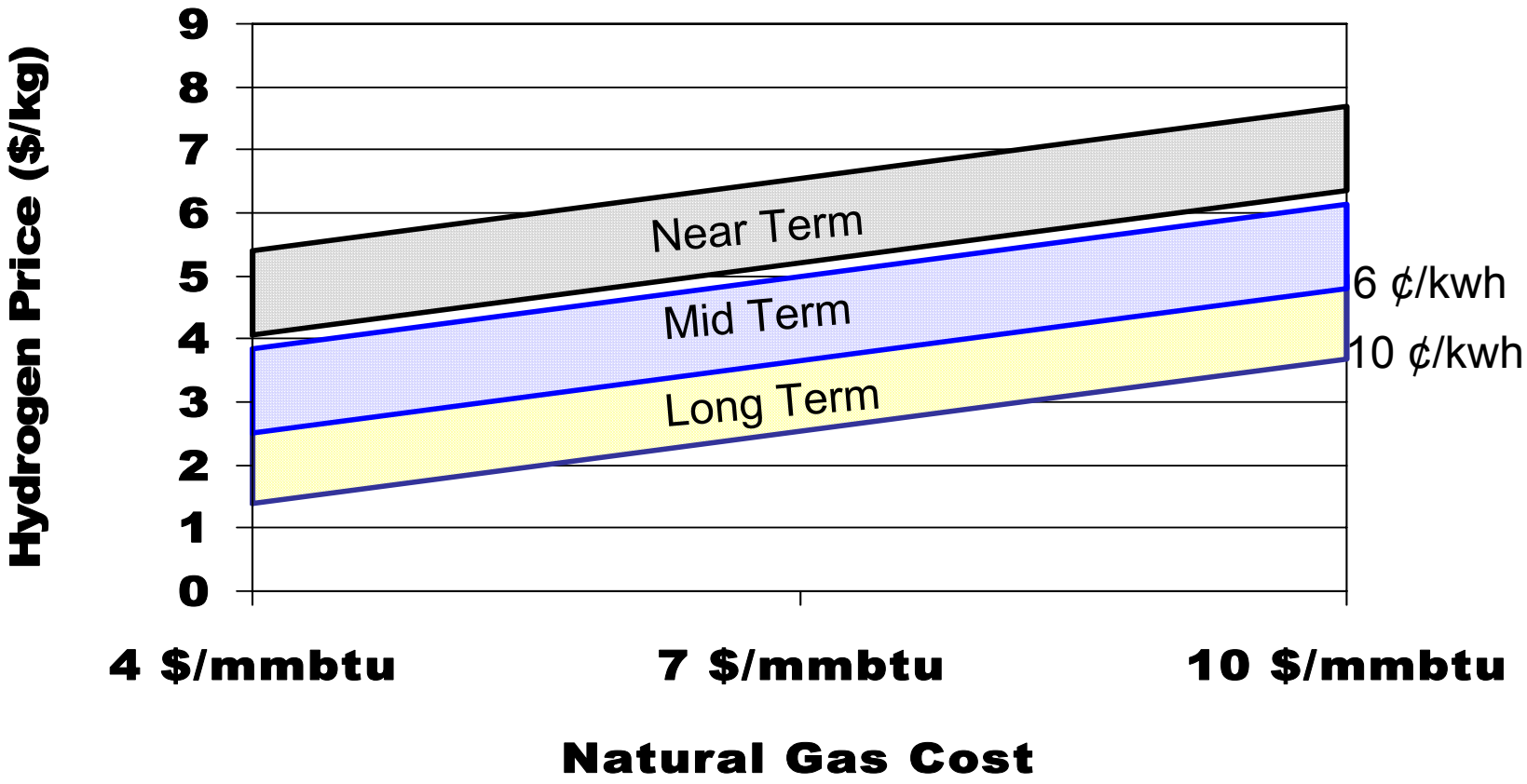
- Hydrogen Purification Development Completed
- PFD Completed
- Preliminary H & M Balance Completed
- Preliminary P&ID (Rev 0) Completed
- Preliminary Hazards Review (PHR) Completed
- Estimate for Phases 3 & 4 Completed
- Updated Economics
- Developed Host Site Short List

- Phase 3 Go Decision Executed

Purification Development Program

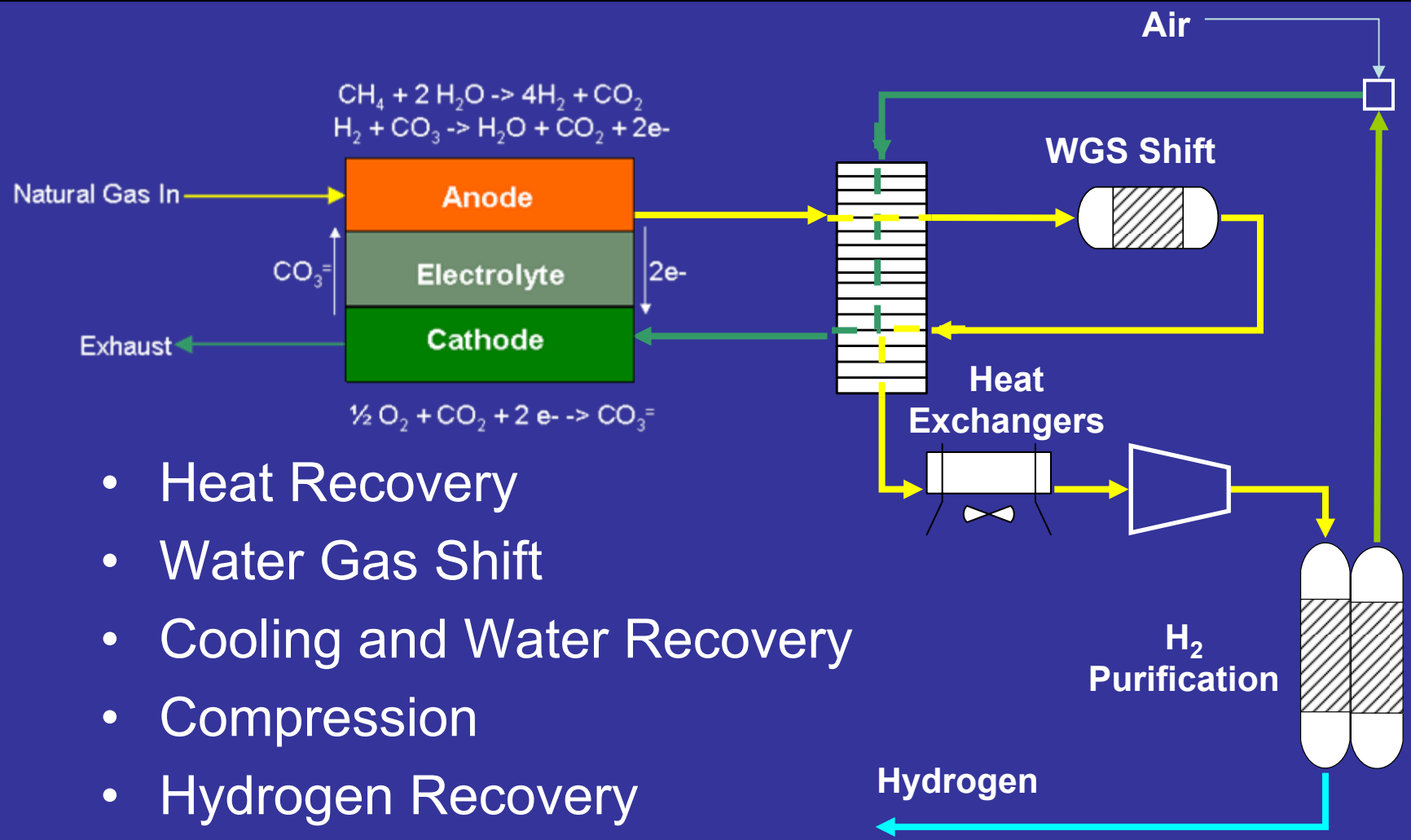
- Investigated >25 Technologies
- Selected Advanced PSA Process
  - Cycle Simulation Completed
  - Adsorbent Mix Selected
  - Lab Testing Completed
  - Pilot Plant Verification Completed
  - Optimized PSA System
  - Patent Applications in Progress

Hydrogen Energy Station Economics



Basis: Feedstock = NG; 1200 kW Power; 700 kg/day hydrogen; No heat sale

Hydrogen Co-production using MCFC



- Heat Recovery
- Water Gas Shift
- Cooling and Water Recovery
- Compression
- Hydrogen Recovery
- Tailgas Integration

Phase 3 – Detailed Design & Construction

- **Detailed Design**
  - Anode Gas Handling - Complete
  - WGS Reactor - Complete
  - Hydrogen Purification - Complete
  - Integration - Complete

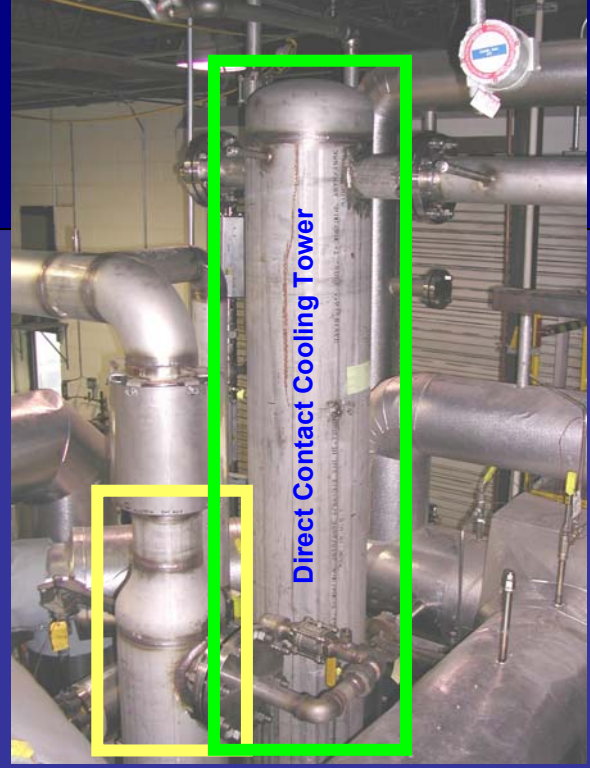
- **Site Selection - OCSD**
  - Orange County Sanitation District
  - Fountain Valley, CA
  - Sewage Treatment
  - Replace ICE stationary emitter with HES

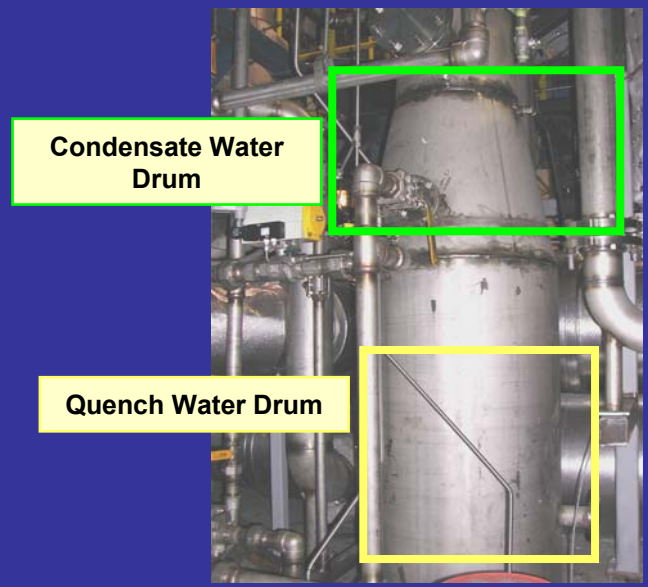
Anode Gas/Cooling Components

- Fuel Cell Operation at H2 Export Design Conditions
- Heat Exchanger Train
- Direct Contact Cooling Tower
- Shift Reactor at high space velocity
- Electrolyte Filter

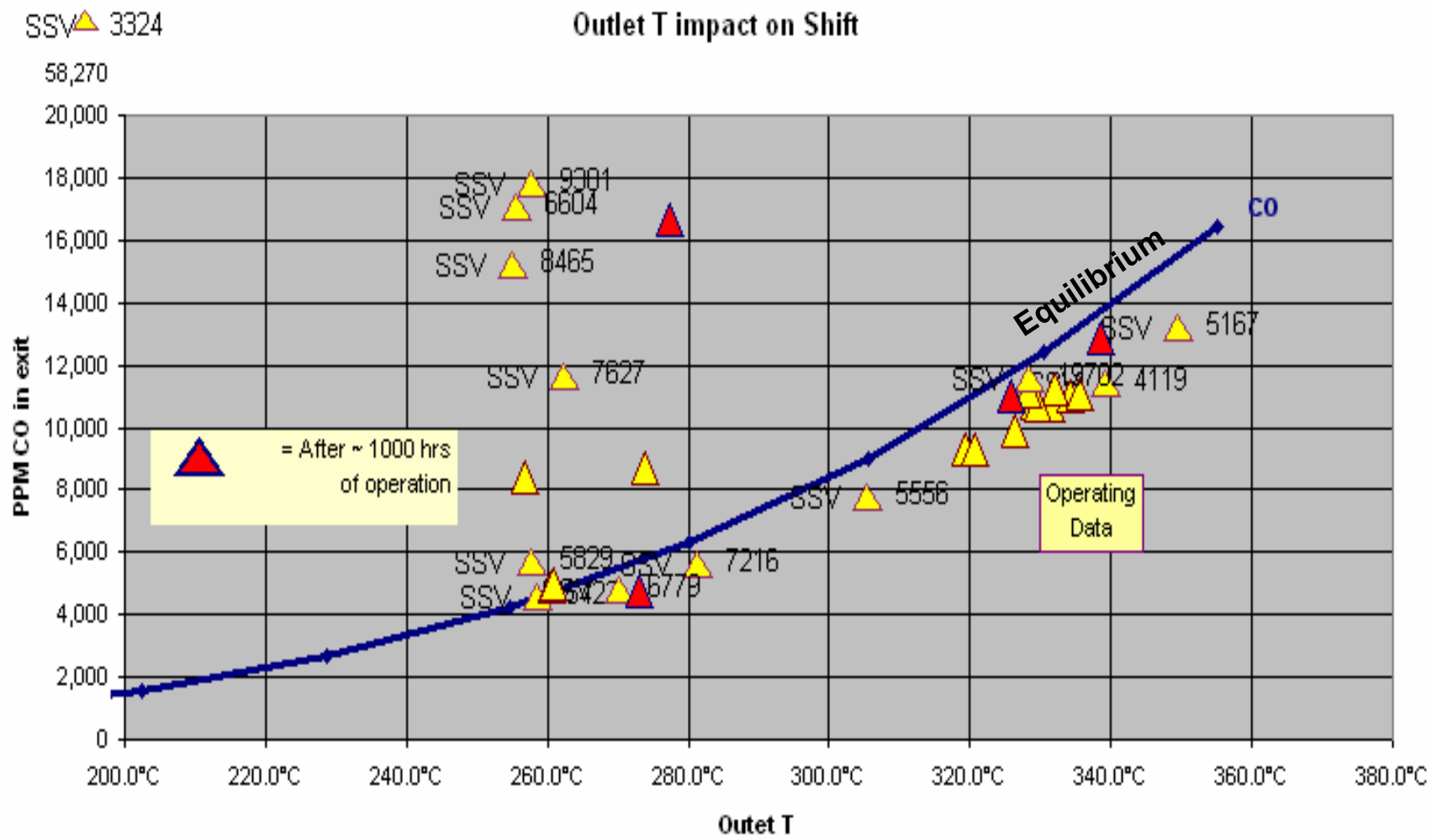
Direct Contact Cooling Tower

- Lower Cost / Lower Pressure Drop compared to Air Fan
- Heat of Condensation Provides Useful Hot Water (~170 F)
- Lower portion of tower provides water suitable for humidifying fuel and quench.





WGS Reactor Performance Data



Purification System Design

- PSA System Design Completed - PFD, P&ID, H&MB
- Performance: 80+% Recovery @ FC Grade
- Compressor Specified and Selected
- Process Control Strategy Developed
- Equipment Quotes and Fabrication Estimates Completed
- Installation Costs Estimated

Integrated Hydrogen Energy Station

Integration Issues Resolved

FuelCell Energy

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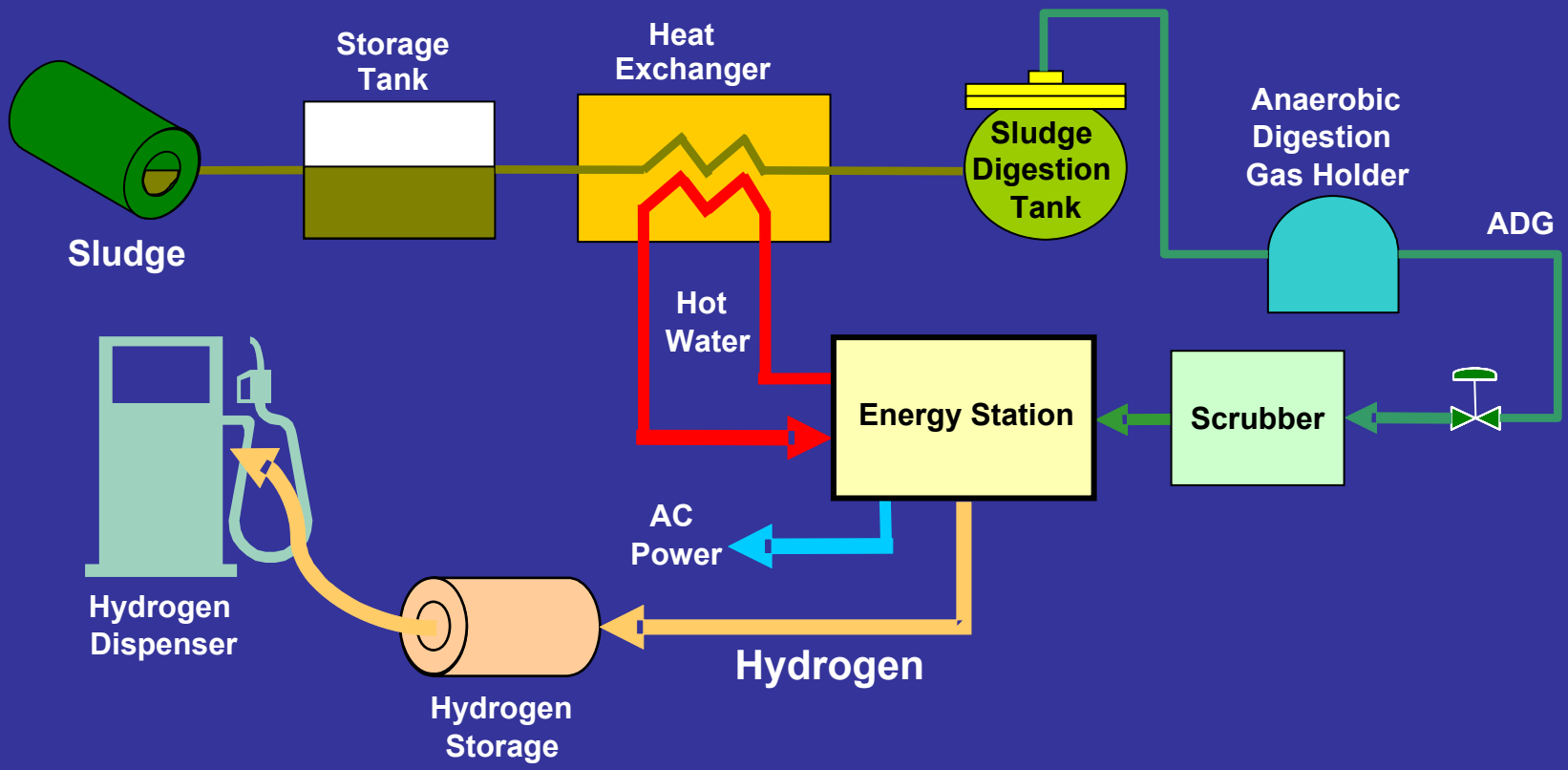
Future Work

- Modify Agreement for Digester Gas
- Complete Phase 3 (FY07)
  - Order Equipment
  - Fabricate Skids
  - Assemble and Test Complete System at FCE
  - Update Economics
  - Go-No Go for Phase 4
- Phase 4 (FY ‘08 - ’09)
  - Install at Selected Site
  - 6 Month Demonstration

Digester Configuration



Examples of Digester Gas Fed DFC® Plants

Wastewater Treatment, Santa Barbara,CA

Kirin Brewery, Japan

Sierra Nevada Brewery, California

FuelCell Energy

Digester Gas Process Impact

- Requires Feed Compression
- Requires Fuel Prep Equipment
  - Remove H_2S from feed (main contaminant)
  - Remove trace contaminants (Siloxanes, Other sulfur compounds)
  - Reduce moisture in feed
- Design Provided at NO COST to Project
- Deoxidizer added to DFC unit
- Increased CO_2 to PSA
  - Compressor power increases
  - Slightly lower H_2 recovery

Digester Gas Performance Impact: Minimal

	Units	NG	Biogas
Overall Efficiency – "Tri-Gen" (Net Power + Hydrogen + Heat) / (Fuel)	LHV	76%	70%
Overall Efficiency – H2 + Power (Net Power + Hydrogen Product) / (Fuel)	LHV	66%	63%
Hydrogen Product	Kg/day	~ 175	~160
Net Power	kW	~ 250	~ 240
Heat Export	kW	~ 75	~ 50

Biogas has no impact on MCFC
Small impact on PSA performance due to higher CO2 in gas to PSA

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Thank you

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